The ALMA LESS survey

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pre-ALMA

APEX

with ALMA

ALMA

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Epoch of Galaxy Formation

The UV/optical Universe:
The Hubble Ultra Deep Field

- Background in UV and optical is mainly dominated by stars (rather than AGN)
- Luminosity density can be used to track the evolution of the star-formation with redshift to identify the epoch of galaxy formation

Hopkins & Beacom 2006
- Most luminous FIR gals at z~0 are UltraLuminous InfraRed Galaxies (ULIRGs)
- $L_{\text{FIR}}>10^{12} L_\odot$, inferred SFRs 100's $M_\odot/\text{yr}$
- >95% Luminosity comes out in FIR ($\sim10$-1000um)
- Host <1% of star formation at z=0 - maybe more important at high-z?

**HST - optical**

**Herschel 250-500um**

- COBE showed that ~50% of the light produced by extra-galactic objects has been reprocessed by dust and re-emitted in the far infrared and sub-mm.

- Far Infrared background = opt/UV --> half of the energy production (from SF or AGN) over history of the Universe arises in highly obscured regions


\[
\int [\text{opt/UV}] = \frac{1}{2} \int [\text{SF or AGN}]
\]
The negative k-correction in the sub-mm wave-bands
LABOCA Extended Chandra Deep Field South Survey (LESS)

The ECDFS is the prime extra-galactic survey field, with wealth of multi-wavelength data from Chandra X-ray; UV/optical+mid-IR; HSO SPIRE; APEX LABOCA and VLA radio.

LESS is a contiguous & uniform 870$\mu$m survey, reaching $\sigma_{870}=1.2$mJy over $\sim30\times30'$

Adding Herschel imaging does not improve situation for IDs since resolution is $\sim15''$, 25'' and 35'' at 250, 350 & 500$\mu$m
The ALMA LABOCA Extended Chandra Deep Field South Survey (A-LESS)

Survey all 126 sub-mm sources in ECDFS at 870um (345GHz) to depth of 0.3mJy in compact configuration.

2 mins / source (c.f. 300hours with APEX to 1.2mJy)

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Crucially, at a resolution of 1.4”
• 96 ALMA SMGs
• Calibrate against 5900 field galaxies in ECDFS
• ~25 SMGs with spec-z's
• Derive photo-z for 77 SMGs with > 3 band photometry

BUT:
• 19 SMGs (20% of sample) have 0-1 detections (9) or 2-3 detections (10) in UV/optical/NIR/mid-IR bands
• Real or just S/N effects in 870μm catalog?
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Magnitude distribution and stellar mass

Assume to $z=2.5$ we have "correct" $M_H$ distribution

MC to derive underlying distribution at $z>2.5$
Herschel SPIRE 250, 350, 500 μm imaging allows us to improve measurement of far-IR SEDs of ALMA SMGs

But need to deblend SPIRE maps (use 24 and radio imaging as prior catalogs)

Swinbank et al. 2013 MNRAS submitted
25+/-3 % peak at 250µm (<z> ~ 2.3)  
38+/-3 % peak at 350µm (<z> ~ 2.5)  
37+/-8 % peak at 500µm (<z> ~ 3.5)
Composite rest-frame SED of 99 ALESS SMGs
Integrating to $S_{870} = 1$ mJy, SMGs host ~20% of cosmic SFR density at $z=2$. 
SMG Evolution to $z=0$

Take $N(z)$; SFR; average lifetime and H-band fading (assume single burst) and calculate the space density of descendants at $z=0$.
SMG Evolution to $z=0$

If the burst has a $\sim 100\text{Myr}$ duration (compatible with the gas depletion timescales from $M_{\text{H}_2}/\text{SFR} \sim 4 \times 10^{10} M_\odot/400 M_\odot/\text{yr}$) and they only go through one burst then the space density and mass weighted ages of the faded SMG descendants are compatible with the majority of bright Elliptical galaxies at $z=0$.

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![Graphs and images related to SMG evolution and burst characteristics](image)
Projects/Papers:

2. High resolution sub-mm counts. Influence of blending on counts (Karim et al. 2013 MNRAS 432 2).
4. OI 63-um detections in ALMA SMGs (Coppin et al. 2012 427 520)

5. N(z), stellar masses and evolution to z=0 (Simpson et al. 2013 ApJ submitted)
6. FIR colours, luminosities, SFRs (Swinbank et al. 2013 MNRAS submitted)
8. Sub-mm properties of star forming BzKs and BX/BMs from ALMA (Decarli et al. 2013 ApJ submitted)

9. FIR--radio correlation of ALESS SMGs (Thomson et al. 2013 in prep)
10. Energy balance in ALESS SMGs (E da Cuhna et al. 2013 in prep)

11. The rest-frame optical morphologies of ALESS SMGs from HST (Simpson et al. 2014 in prep)
12. zLESS: The redshift distribution and star formation histories of ALESS SMGs (Danielson et al. 2014 in prep)
13. A high resolution sub-mm continuum and HST morphological analysis of SMGs (Hodge cycle 1 program)
Conclusions
ALESS: 345GHz continuum mapping of 126 SMGs in ECDFS has produced unbiased sample of 99 robust SMG.

~1.4” resolution maps yield a high detection rate: ~50% single IDs; 30% multiple IDs; 20% blank maps. 1 SMG is resolved at 1.4” (12kpc) resolution. AGN fraction in ECDFS appears low - only 10% of ALMA SMGs detected in X-rays by Chandra.

Redshift distribution suggests <z> =2.5±0.2, with a significant (but not dominant) tail to z~5.

Fitting the rest-frame FIR SEDs, the bright SMGs account for ~2% of the cosmic SFR-density at z~2. Integrating to 1mJy, this rises to ~20%.

Accounting for the fading, the SMG descendent space density and magnitude distribution is consistent with the population of morphologically classified luminous ellipticals.
**ALESS: towards a full SMG catalogue**

- 122/126 fields around LESS targets observed in Cycle 0
- 88 (strictly random) maps of homogeneous quality
- 99 SMGs at $>3.5\sigma$ significance from the “best” maps (expect 1 spurious + 1 missed)
- 32 SMGs at $>4\sigma$ significance from maps with poorer noise or outside PB (≈30% incompleteness)

Robust counterparts: Reliability 80% but Completeness 45%; Robust + Tentative: Reliability 65% but Completeness 55%

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[Image of Optical Image + SPIRE contours, ALMA image + radio contours, and confirmed SMGs]